Honorable Lee Hamilton, Co-Chair
Honorable Brent Scowcroft, Co-Chair
Blue Ribbon Commission on America's Nuclear Future

The Commission has a challenging assignment of recommending actions the Federal government should take for the management of government-owned spent fuel and high level waste and for management of the back end of the civilian fuel cycle. Government actions related to the civilian fuel cycle will have an effect on the future development of civilian nuclear power and its contributions to the development of a domestic low-carbon future and contributing to meeting U.S. nonproliferation goals.

This note presents my thoughts on the three major areas the Commission is investigating.

The first area, interim storage and transportation of spent fuel, is the most independent of the three. It is recommended that the nation continue with and build on its successes at the storage and transportation of spent fuel.

The second area, the establishment of a national geologic repository for spent fuel and high level waste, has been a failure. It is recommended that the program be separated into defense and civilian components and that the civilian component be revised to adopt elements of the management and regulatory model that has been more successful for other waste management programs: industry management of site development and operation accompanied by state regulation for compliance to federally established standards.

The third area, the nuclear fuel cycle, presents different issues depending on where the technology is used. The existing fuel cycle technologies are considered acceptable when used in a developed country, particularly one that already has nuclear weapons. A reasonable course of action would be to let the technology evolve as it has been doing to improve physical and economic performance. The same technology, particularly uranium enrichment or PUREX-based reprocessing technology, is viewed very differently if it is deployed in a developing or a non-nuclear weapons country. Such deployment is viewed as presented a proliferation risk because these technologies were originally developed as part of national weapons programs. At the present time, the general approach for managing such risk is to attempt to establish reliable fuel supply arrangements to discourage the deployment of such sensitive technology in developing countries. This strategy creates two classes of countries and its long-term viability is questionable.

An alternate nonproliferation strategy would be possible if one had a more proliferation resistant, more cost-competitive fuel cycle could be used with a reactor that was as safe as but more cost-competitive than current light water reactors. If such reactor-fuel cycle technologies were available, they could represent a game-changing tool for addressing two priority issues: a low carbon future and nuclear nonproliferation. There is the potential that such technologies could be developed if the government were to tap the nation's skills at innovation.

It is recommended that the government place a very high priority on tapping the nation's innovative spirit and make a realistic assessment of the potential for the development and deployment of such innovative technologies over the next few decades, a timeframe much longer than that necessary for the initial development and industrial deployment of technologies to support nuclear weapons. It this assessment is positive, the nation should create a technology neutral environment that encourages industry-government partnerships to develop and deploy such technology to meet the nation's and the world's need for clean, safe, cost-competitive energy.

The subsequent pages of this note discuss these ideas further. I hope these thoughts are useful as the Commission collects information and develops its recommendations.

Sincerely

James Hammelman

- **Interim Storage and Transportation of Spent Fuel.** The existing system for interim storage of civilian spent fuel was developed to meet NRC requirements, primarily those of 10 CFR Part 72, and it is working well. There are about a dozen independent spent fuel storage installations in operation in the United States. The existing system has provided and is expected to continue providing protection of public health and safety while keeping the spent fuel in a condition that retains future spent fuel management options.[1] The system has demonstrated flexibility in being able to accommodate different fuel types and different storage designs.

  The DOE has successfully adopted the designs developed for the storage of spent civilian fuel to systems for the storage of defense fuel not intended for processing.

  There is also an existing system for transportation of spent fuel although it has been used only minimally in the last decade or so. Previously (over the last 30 years) there have been thousands of spent fuel shipments with most of these shipments occurring between different reactors owned by the same utility. There has been additional radioactive waste transportation experience with the shipment of hundreds of thousands of cubic feet of low level radioactive waste every year between waste generation sites and waste disposal sites.

  <u>It is recommended that the current system for interim storage of spent civilian fuel and waste shipment be maintained and refined as necessary to respond to any future issues. It is also recommended that DOE continue to adopt the certified commercial spent fuel storage designs and practices for the long-term storage of any spent fuel it does not intend to process.</u>

[1] The NRC issued an update to their waste confidence decision in a Federal Register notice of October 9, 2008 which included a statement that it has reasonable assurance that spent fuel can be stored safely without significant environmental impacts for at least 60 years beyond the licensed life of the reactor through the use of either reactor spent fuel storage basins or independent spent fuel storage installations.

- **Establishment of a Geologic Repository.** National and international reviews of options for managing spent fuel and high level radioactive waste have consistently concluded that deep geologic disposal is the preferred method of management. Even though there have been problems establishing a national geologic repository, geologic disposal at an appropriate site(s) continue to be the most attractive option for the disposal of spent fuel or high level waste.

  Historically the national program for development of a geologic repository for spent fuel or high level waste has been a large Federal program define by Congress and implemented by multiple Federal agencies. The program has bogged down for two major reasons:

  - Some individuals and organizations believe that the repository would represent unacceptable short-term and long-term risks to the individuals and population around the repository. In addition, some believe stated that the scientific understanding of the long-term performance of the site and repository design features is not adequate to demonstrate compliance with the long-term dose standards which are a small fraction of current background dose levels.[2]

  - The high-level waste program that is Federally (Congressionally) defined, large (a single repository for civilian and defense waste), Federally implemented (DOE), and Federally regulated (EPA and NRC). The program looks like a steam roller to individuals and organizations near potential repository site. There is minimal role for local and state organizations to engage in negotiations about the size of the program, features of the repository, or the nature of any compensation to any region hosting the repository. In addition, there are minimal opportunities for any state involvement in regulatory oversight.[3]

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[2] There is inherent uncertainty about the long-term performance of any natural or engineered system and the uncertainty increasing the further one predicts into the future. The high-level waste disposal arena is the only one where predictions of long-term degradation of natural and engineered barriers are required over thousands of years or longer, timeframes that are difficult to imagine. The disposal of hazardous waste in deep injection wells which is regulated under 40 CFR Part 148 involves long-term migration predictions, but the predictions are based on the assumption of no change in the geologic setting and engineered barriers performing as intended. These regulations do not call for analysis of scenarios that involve future human intrusion in the waste disposal horizon. A 1990 National Academies Board on Radioactive Waste Management report characterized the regulations which require advance definition of the technical performance requirement for each part of a multibarrier system as possibly being a "scientific trap" where the public in encouraged to have such expectations and waste disposal program managers believe such certainty is possible. The report also stated "Pursuing that illusory certainty drives up costs without delivering the results promised or comparable benefits." No other actions require evaluation of impacts thousands or millions of years into the future.

[3] Many other environmental or waste management regulatory programs are defined at the federal level with the states being given an opportunity to establish their own regulatory programs to implement the federal standards. This occurs with EPA regulations and NRC regulations for low-level waste disposal.

It is recommended that the large Federal program be separated into smaller projects and the states be given a larger regulatory role in negotiating the size of any repository within their boarders as well as a larger role in regulating any repository. It is also recommended that the program be reshaped to follow a process that is similar to that used for other long-term waste management programs in the nation. In more specific terms:

- The program for development of geologic disposition should be separated into at least two programs, one for commercial spent fuel and high level waste and one for defense spent fuel and high level waste. It may be appropriate to allow the commercial program to be broken down further on a regional or compact basis as is done for low level waste disposal and was done for the Private Fuel Storage project.

- The repository standards should be expanded to include the use of more reliable near-term predictions and to encourage the use of site, design and operational features that show a promise of being able to confine the waste and able to adapt to future improved understanding of the performance of the site and the design.[4] The revised standard should retain the use of long-term performance assessment, but the assessment should be used to gain insight in which waste components must be contained and which transport processes and pathways must be controlled to keep minimize long-term impacts.[5]

- Host states should be given the option of regulating waste disposal in accordance with national standards as is done with other nuclear and hazardous waste management programs.

- The programs for the development and operation of the repositories for civilian waste should be managed by nuclear power industry. The federal government should have the authority to review the program and reject any plans it believes would jeopardize the long-term performance of the repository which it will own.

- The funding for the civilian repository program should be maintained in a special separate fund similar to an NRC-approved decommissioning fund for a nuclear power plant. The federal government should approve expenditure plans as it holds title to the repository.

- The program for the development and operation of the repository for defense high level waste should be managed by the federal government.

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[4] This portion of the recommendation is consistent with the spirit in a 2003 report by the National Research Council's Committee on Principles and Operational Strategies for Staged Repository Systems titled *One Step at a Time: The Staged Development of Geologic Repositories for High-Level Radioactive Waste*.

[5] This use of performance assessment is consistent with the observations reported by the National Research Council Committee on the Waste Isolation Pilot Plant in their 1996 report *The Waste Isolation Pilot Plant: A Potential Solution for the Disposal of Transuranic Waste*.

- **Improvements in Nuclear Power Technology**.

  Nuclear power could be a powerful tool for helping the nation and the world meet their needs for energy production with minimal environmental impact and help reduce the linkage between nuclear power and nuclear weapons if (1) there were reactors that were as safe as or safer than current reactors but more cost competitive and (2) the reactors used a fuel cycle that didn't have the potential to shorten to path to nuclear weapons.

  I believe it is possible to develop complimentary reactor and fuel cycle technologies that are more responsive to the above needs of the 21st century. The following paragraphs outline the features of reactor and fuel cycle technologies that I think could be developed and integrated into more attractive nuclear energy systems.

  A safer, more cost competitive reactor would have features that allow simplification and increased reliability of the engineered systems used for (1) reactor power level control, (2) transport of heat from the core region to the electrical generation system, (3) decay heat removal and (4) secondary confinement in the event of failure of the primary coolant boundary. Such simplification should be easier to achieve if the reactor used a coolant with good heat transfer capability, low pressure and low chemical reactivity.[6] One example of such simplification which achieves some of these features is a reactor with the injection of water above the core region of a heavy metal cooled reactor in order to eliminate the need for steam generators and main coolant pumps. While this specific design may not meet all the desired objectives, it illustrates the type of simplification that should be investigated to increase safety while reducing costs.

  A more proliferation resistant fuel cycle would be one that (1) uses material that is less attractive for a nuclear weapon and (2) uses processing facilities can not be adopted, directly or with simple modification, to shorten the time for the production of material that is attractive for a nuclear weapon. It appears that the first objective could be met through the use of fuel material that involves a broad mix of plutonium isotopes and separation processes that are not efficient for the production of high purity plutonium. It appears that the use of a broad mix of plutonium isotopes, including Pu-238 and Pu-240, would present a far less attractive material for a nuclear weapon than highly enriched uranium (HEU) or plutonium with a high fraction of Pu-239. The inclusion of a heat source with the plutonium further increases the difficulty of using the material in a weapon.[7] The second objective, a facility not easily adapted

[6] The low pressure system would simplify the design of the primary containment system and reduce the potential for the transport of contamination away from the reactor core in the event of primary containment failure, particularly at higher than normal temperatures.

[7] A paper by G. Kessler et. al., "A new scientific solution for preventing the misuse of reactor-grade plutonium as nuclear explosive", *Nuclear Engineering and Design*, 238 (2008) 3429-3444, presents neutronic and thermal analysis of "hypothetical nuclear explosive devices" that illustrates the difficulty of designing a nuclear weapon when using plutonium with higher Pu-238 content and higher levels of internal heat generation.

for the production of material that is attractive for nuclear weapons, would require fuel processing technology is fundamentally different from the current fuel cycle separation technologies that are adaptations of technology initially developed for nuclear weapons programs. A more attractive technology might be developed based on the ideas of (a) chemical processing steps to remove only those spent fuel constituents that are incompatible with recycle fuel (e.g., material that is volatile, corrosive or dilutes the fissile material)[8] and (b) fuel fabrication steps that promptly produce recycle fuel with the fissile material from the chemical processing steps (i.e., no prolonged storage of the fissile material after the chemical processing steps). Overall such a fuel cycle would decrease the attractiveness and accessibility of the fissile material for use in nuclear weapons and would keep the fissile material in a condition approximating the spent fuel standard as much as possible.

In addition to the technical features noted previously, the fuel cycle must be more cost competitive than current fuel cycle systems. The improved cost competitiveness is necessary if the technology is to displace the current technology. The improved cost competitiveness is also necessary in order to make it impossible for a nation to claim that its acquisition of dual use technologies (uranium enrichment, PUREX-based reprocessing) is part of a civilian nuclear power program. Low cost recycle fuel would require a facility that employs a minimum number of chemical processing and fuel fabrication steps and utilizes processes and process equipment that are simple and reliable.

At the present time, neither private industry nor the Federal government are conducting the type of focused, innovative nuclear energy R&D outlined above. Private industry R&D is focused on evolutionary improvements of light water reactors and the low enriched uranium fuel cycle where the R&D costs and technical and regulatory risks are low. The Federal government R&D is currently focused on more general technology development that could be used for future nuclear power systems rather that the near-term development of integrated nuclear power systems that could be "game changers".

If the nation wants to understand if there are innovative nuclear energy technologies that could be powerful and timely tools for changing the trajectory of global CO_2 emissions and reducing the linkage between nuclear power and nuclear weapons proliferation risk, it must find a way to efficiently integrate the nuclear power expertise in the nation into an R&D effort that focuses on technology development and, if appropriate, engineering scale demonstration of promising technologies. The demonstrations must be designed to provide the various parties with the information they need to determine if they could support its commercial deployment.

[8] The voloxidation process which removes volatile components is an example of such a processing step. It could be combined with other processing steps that are selective for removing those components that must be removed to create recycle fuel material. The waste streams from such processing are likely to be different from such processing are likely to be different from the classical definition of high level waste which is generally defined in terms of the first cycle raffinate or its equivalent.

The most promising approach for such integration appears to be a partnership that is focused on the development and demonstration. Such a partnership must include those organizations that could support the technology development and demonstration efforts as well as those organizations that would have to support any commercial development that might proceed after any demonstration phase. In more specific terms, it appears that the primary participants and their most efficient role would be:

- Private industry who has nuclear technology development and operational expertise and would be responsible for any commercial deployment of successful technology.

  Private industry must make some financial investment in the technology development and demonstration effort and select the technologies that would be demonstrated. These actions are necessary to increase the likelihood that any technology selected for demonstration could be commercially deployed.

- The DOE Office of Nuclear Energy which has extensive technology development expertise and facilities and sites that could be used to support any technology development and demonstration efforts

  The DOE Office of Nuclear Energy should provide technical support to the development and demonstration of those technologies selected by private industry. The technical expertise and specialized facilities are critical to efficient technology development progress.

  If the initial technology development is successful and a demonstration is considered necessary, DOE also has the sites that could be used for integrated engineering scale demonstrations.

- Universities who also have expertise and specialized facilities that could support any technology development effort

- The DOE Office of Civilian Radioactive Waste Management (or its successor organization) who would have to accept the spent fuel or high level waste if there is to be an commercial deployment of any advanced nuclear power system

- The NRC who would have to license any advanced reactors or advanced fuel cycles if there is to be any commercial deployment.[9]

[9] The inclusion of NRC as a partner in a demonstration program as something other than a licensing authority is not the normal role for NRC. In fact, such a role may be incompatible with the requirements of Section 202 of the Energy Reorganization Act of 1974. A safety consulting role as outlined in this paper however may be the most time and cost efficient method for NRC staff to develop and understanding of the technology and develop technology specific licensing requirements that would apply if the technology were to be commercially deployed. This approach should also reduce the likelihood that the NRC staff might

> The NRC should support the demonstration effort by reviewing designs and operating plans and identifying potential safety questions that would have to be answered prior to licensing. The agency should also review operating experience any reactor or fuel cycle demonstrations to determine if potential safety questions are resolved or if new questions arise, questions that could be resolved as part of demonstration operations.

Integrated demonstrations are considered to be an integral aspect of the technology development effort and the source of data that can be used by the various participants to determine if they waste to proceed with commercial deployment. The demonstration would provide private industry with the economic and performance information that would let it determine if it wants to invest in commercial deployment. The demonstration would provide DOE with information on the spent fuel or high level waste so that it could decide if it would accept such waste and the fee for such waste management services.

The creation of such a partnership would require the government to create a business environment that encouraged industry to invest in the technology development effort and mandate government agencies to support the partnerships.

<u>It is recommended that the government establish technology neutral incentives for the creation of industry-government partnerships for the investigation and, where appropriate, demonstration of innovative technologies that would improve the cost-effectiveness and proliferation resistance of nuclear power without compromising public health and safety. This should be given the highest priority in order to promptly determine if there are better options for meeting energy demand while minimizing CO_2 emissions and minimizing the increased proliferation risk that can be associated with the further deployment of nuclear energy systems. Some of the specific actions the government might consider include:</u>

- <u>R&D tax credits to reduce the cost of industry participation in such a costly and high risk venture[10]</u>

- <u>Use of government experts and specialized facilities to support the industry-led technology investigation and development efforts[11]</u>

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overlook some safety issue if licensing were performed on the basis of design and design analysis without the benefit of operational experience.

[10] The 2009 report *Tackling U.S. Energy Challenges and Opportunities* by Anadon, Gallagher, Bunn and Jones of the Belfer Center for Science and International Affairs points out the broad support for permanent and expanding R&D tax credit to cover a larger fraction of the costs of energy R&D.

[11] Reports on energy technology innovation including "Stimulating Innovation in Energy Technology" by Bonvillian and Weiss in *Issues in Science and Technology*, Fall 2009 and "From Energy Wish Lists to Technological Realities" by Fri in *Issues in Science and Technology*, Fall 2006 point to the need for industry leadership in the selection and development of technologies intended for commercial deployment. In the case of nuclear energy, it is appropriate for the government to uses its specialized expertise and facilities to support any industry technology investigation and development effort.

- Use of government test sites for appropriate scale demonstrations.

- Limited scale government purchases of electrical power from technology demonstration units

- Modification of NRC charter to allow it to participate as a safety and environmental consultant in any technology demonstration projects.

The use of technology-neutral incentives is a central feature of the recommendations of people who have studied innovation in the energy and other complex industries. [12]

[12] William B. Bonvillian and Charles Weiss, "Taking Covered Wagons East, A New Innovation Theory for Energy and Other Established Technology Sectors", *Innovations*, Vol. 4, Issue 4, fall 2009, MIT Press.